Estimating Groundwater Use from Remote Sensing

Hadi Jaafar

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The Challenge: Water Scarcity in the Arab Region

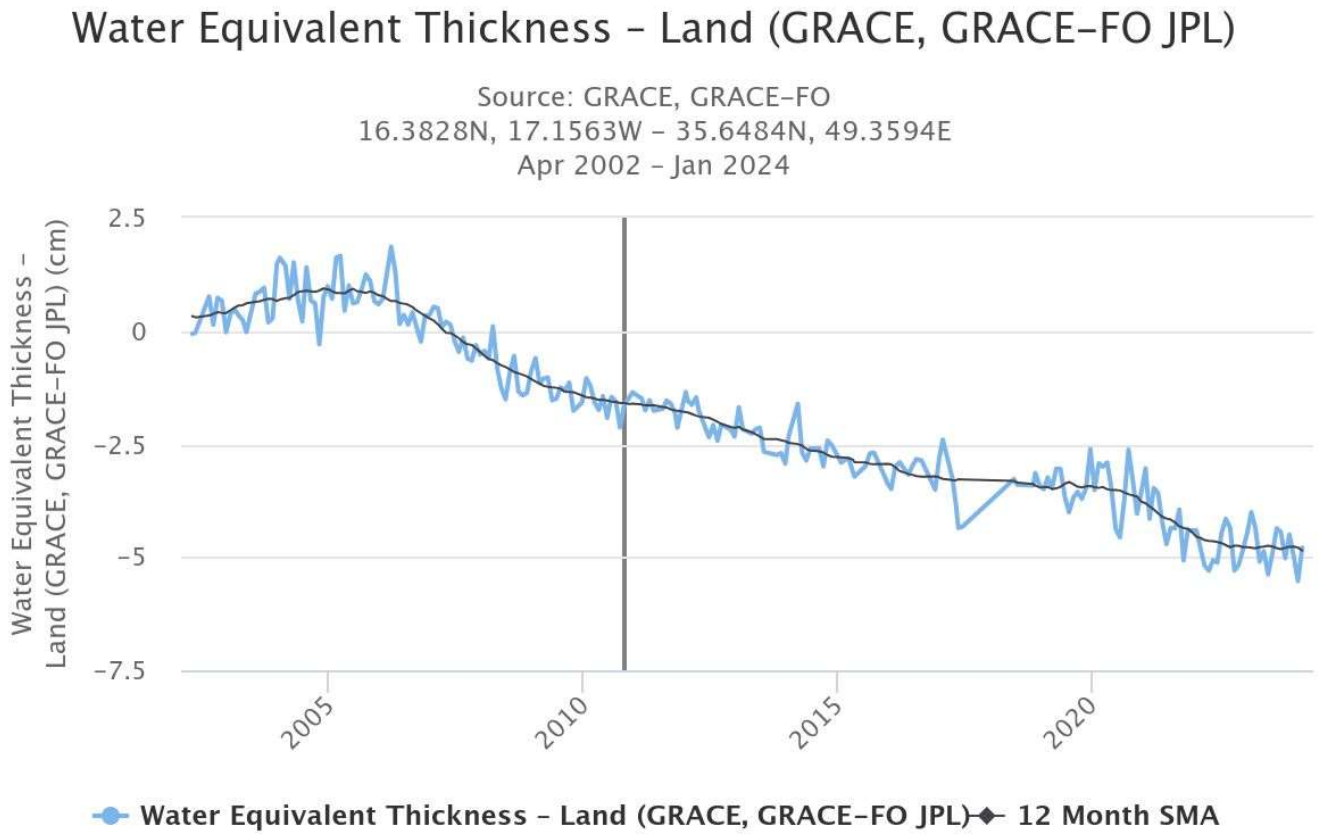
- The Arab region relies heavily on groundwater, the primary source of freshwater for over half of the Arab States.
- Water scarcity is a pressing issue, with overexploitation exceeding natural replenishment rates.
- Excessive groundwater withdrawal, particularly for agriculture with low-efficiency practices, has significantly decreased storage.

Evidence?

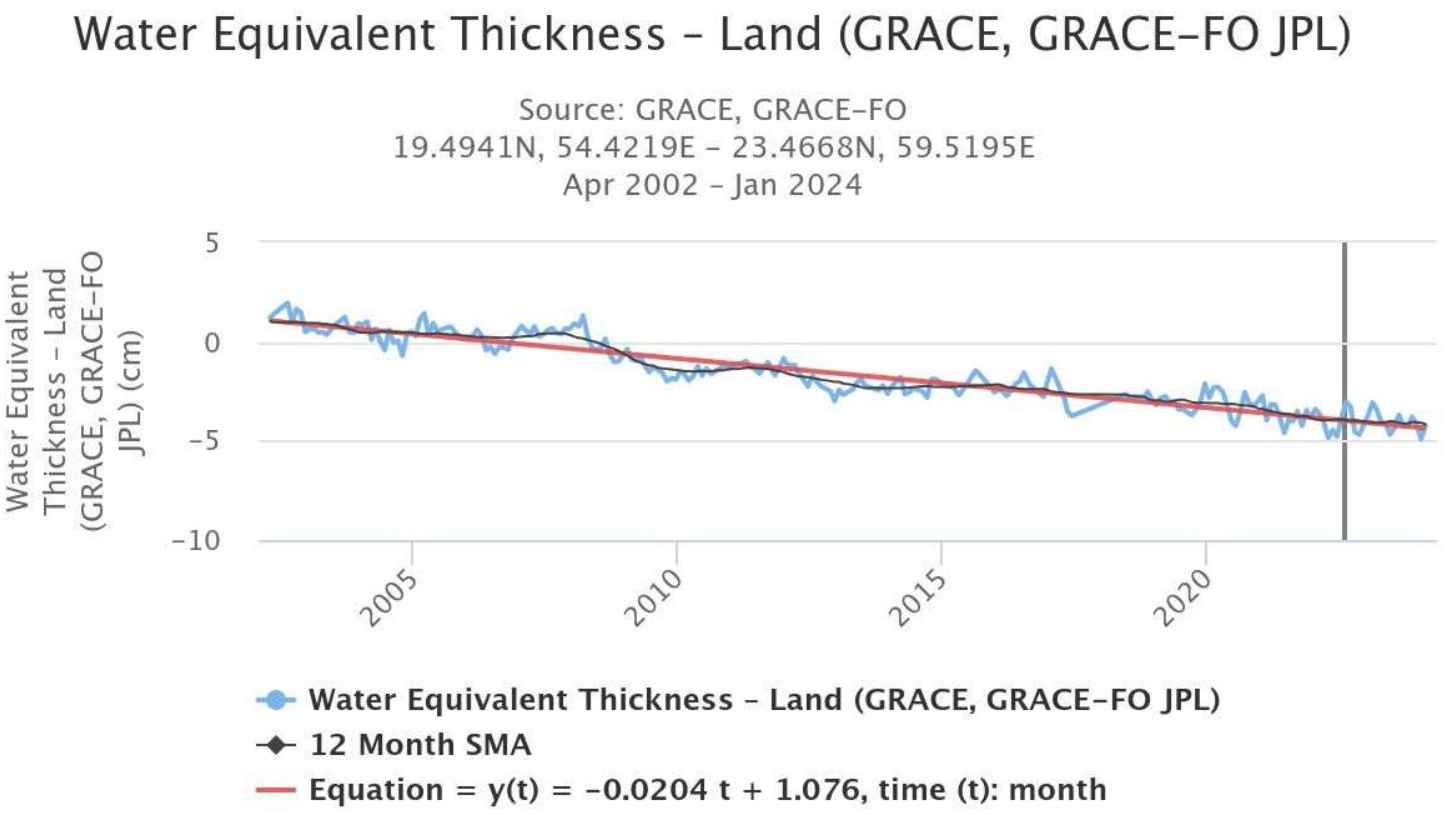
From Remote sensing (https://grace.jpl.nasa.gov/data/data-analysis-tool/)

From Field data

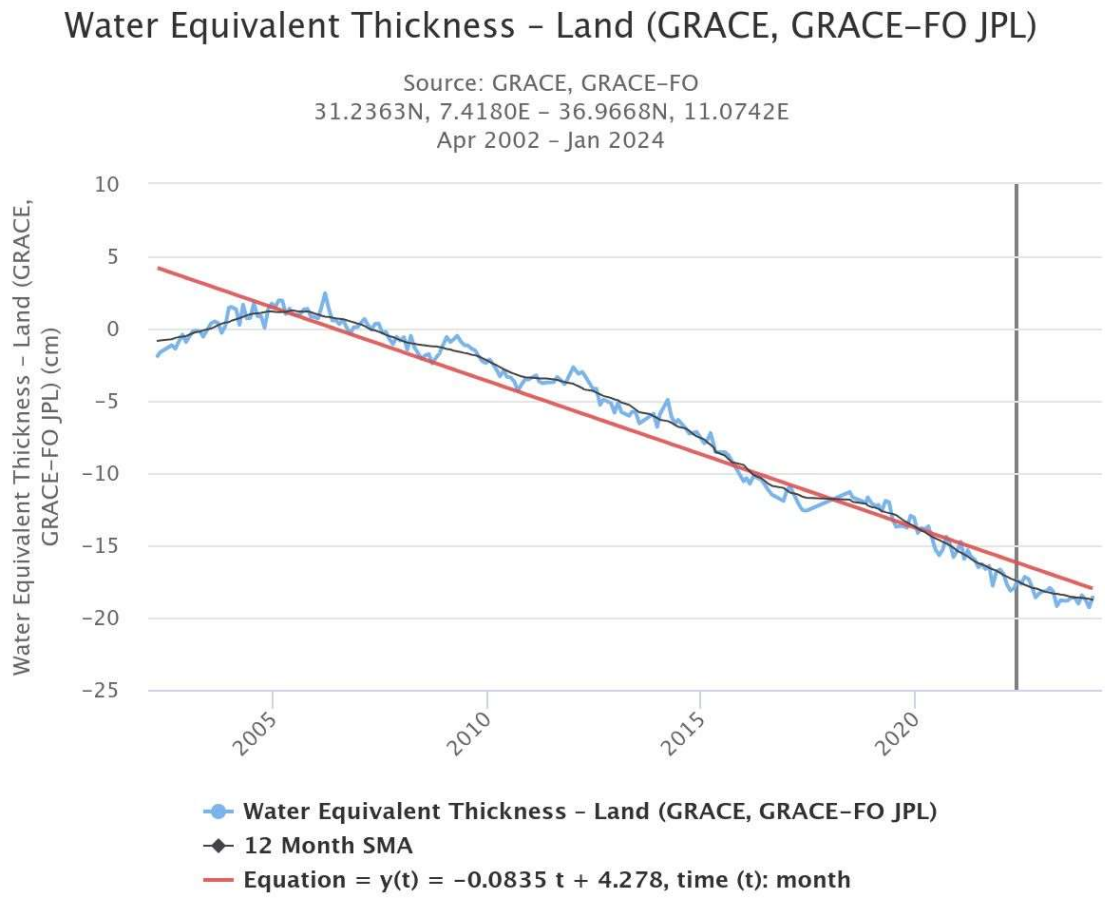
Arab Region

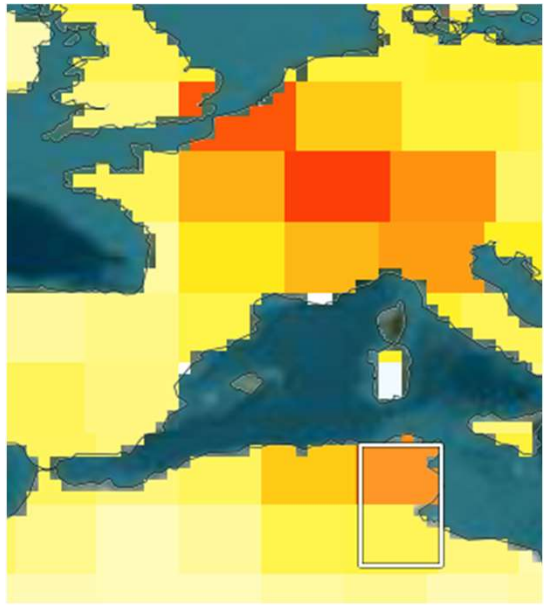

Water Equivalent Thickness - Land (GRACE, GRACE-FO JPL)
Source: GRACE, GRACE-FO
16.3828N, 17.1563W - 35.6484N, 49.3594E
Apr 2002 - Jan 2024
Water Equivalent Thickness - Land (GRACE, GRACE-FO JPL) (cm)
2.5
0
-2.5
-5
-7.5
2005
2010
2015
2020
Water Equivalent Thickness - Land (GRACE, GRACE-FO JPL)
12 Month SMA

Oman (GRACE Data)

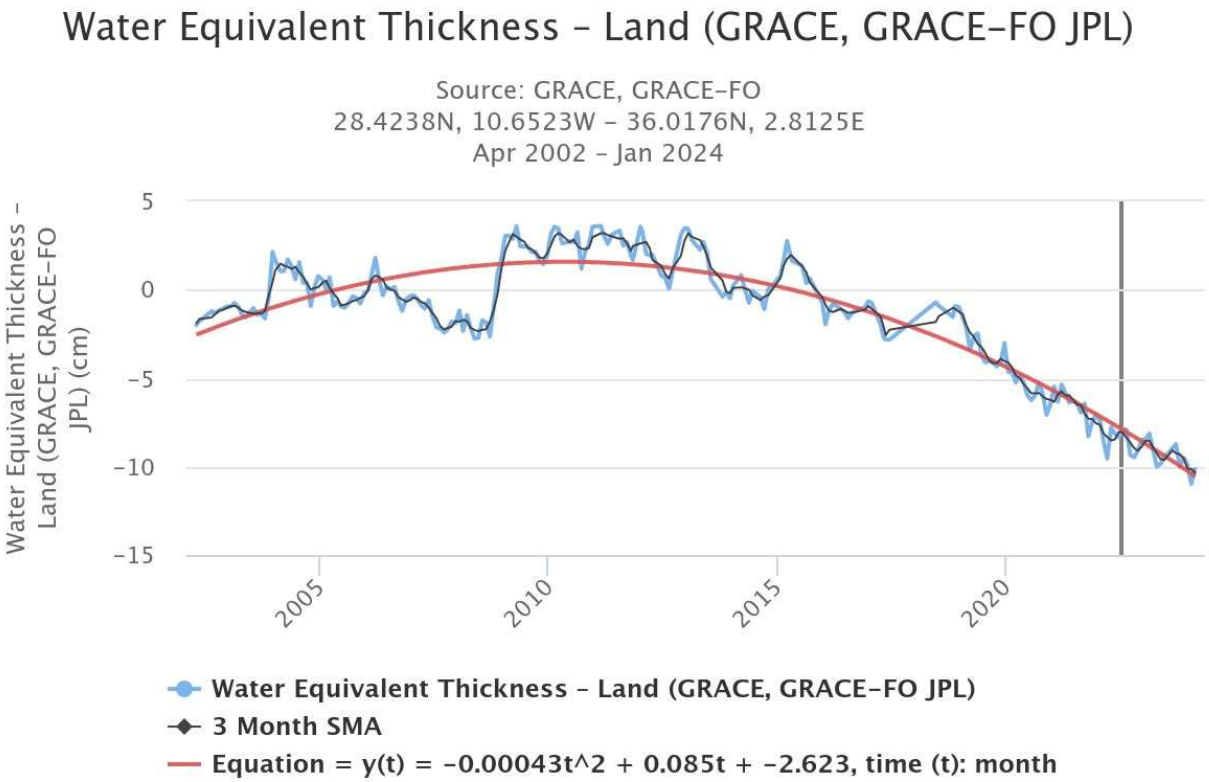


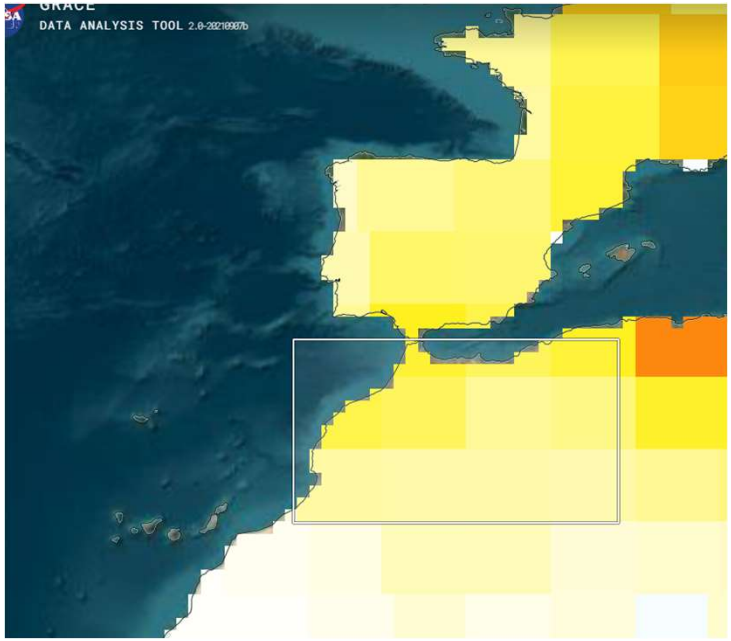
Tunisia (GRACE data)



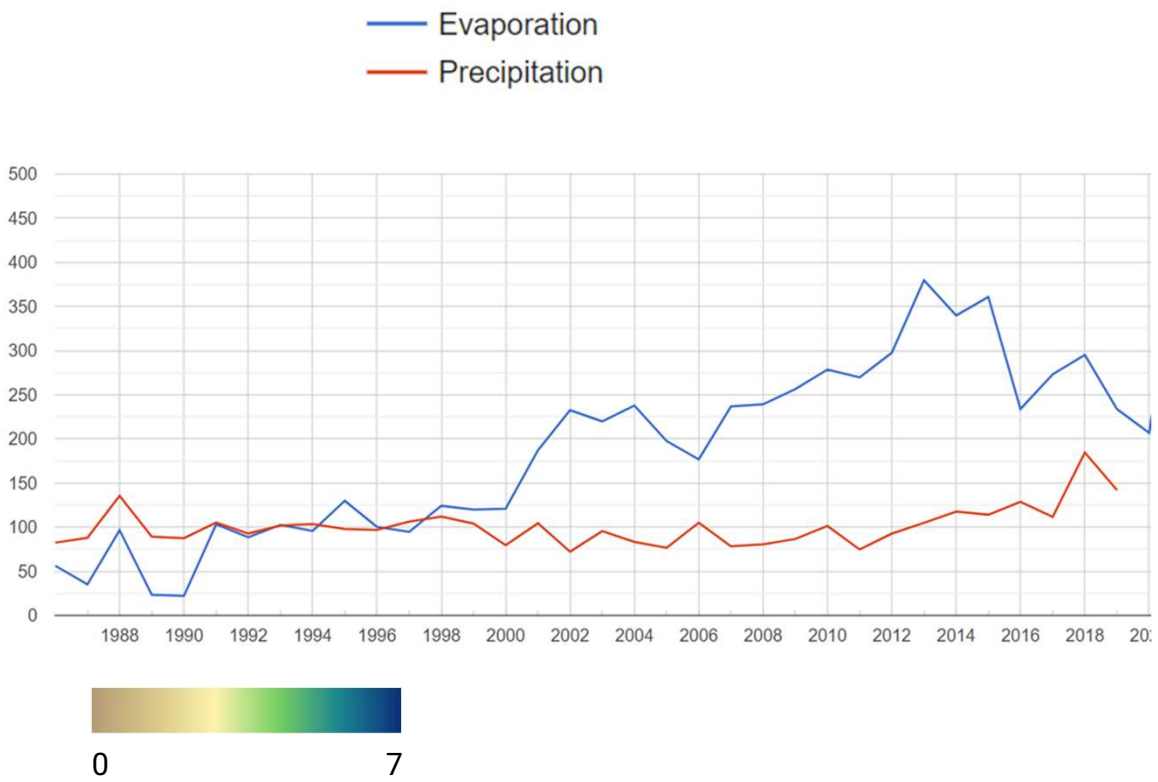


Morocco (GRACE data)






1986

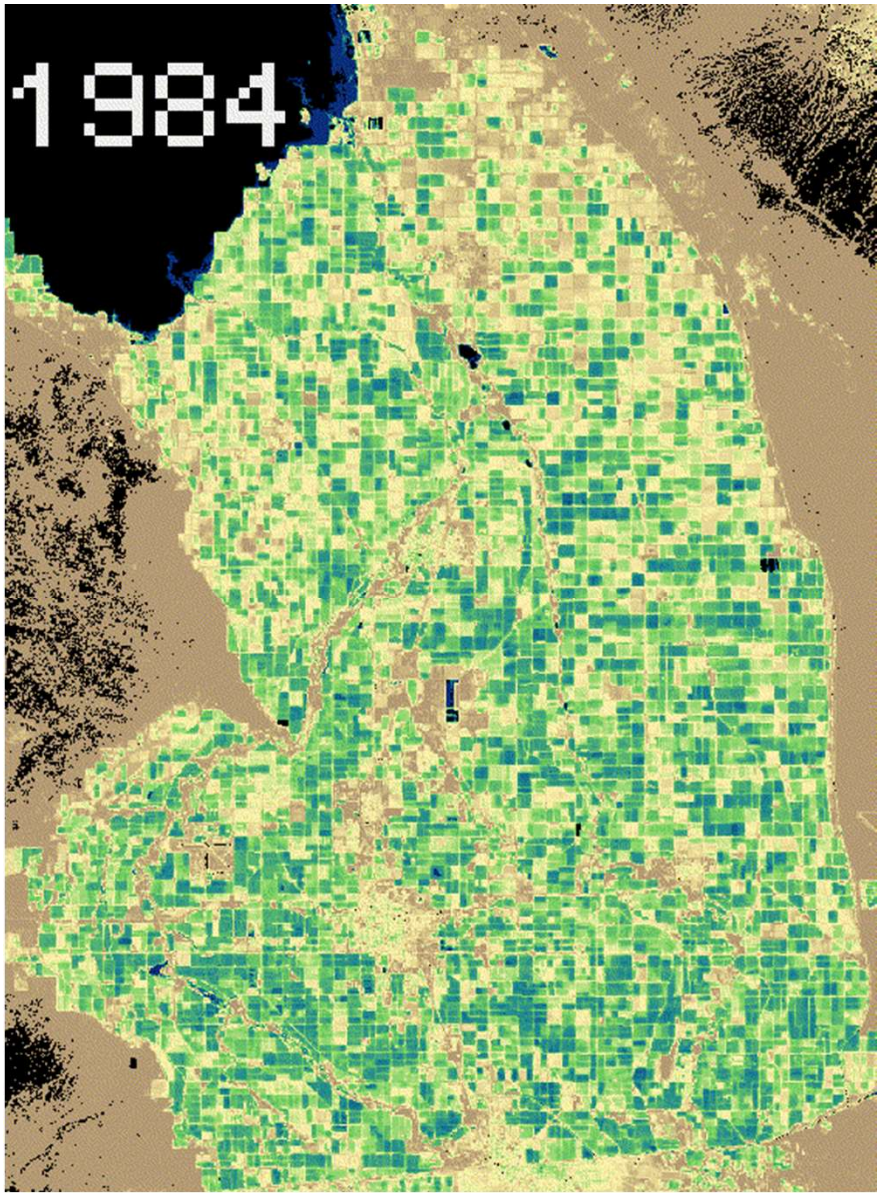

Evaporation
Precipitation
500
450
400
350
300
250
200
150
100
50
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

0
7

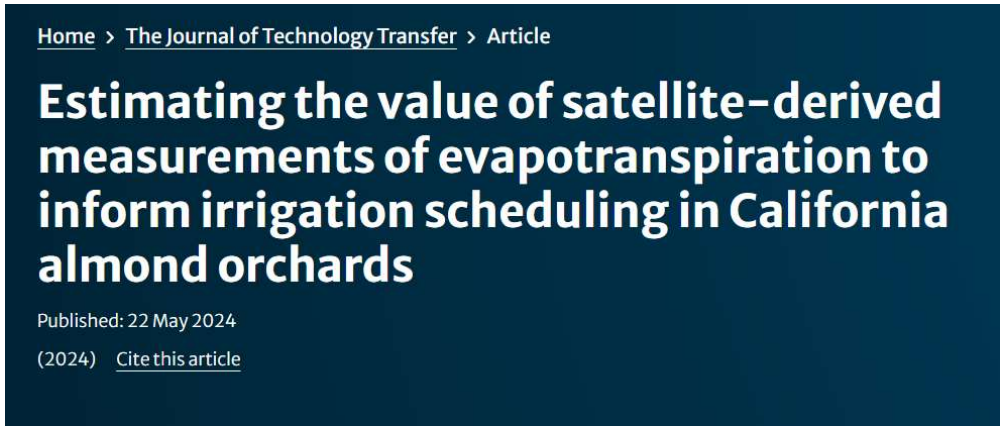
Imperial Valley, CA

Annual 30m- HSEB ET from Landsat

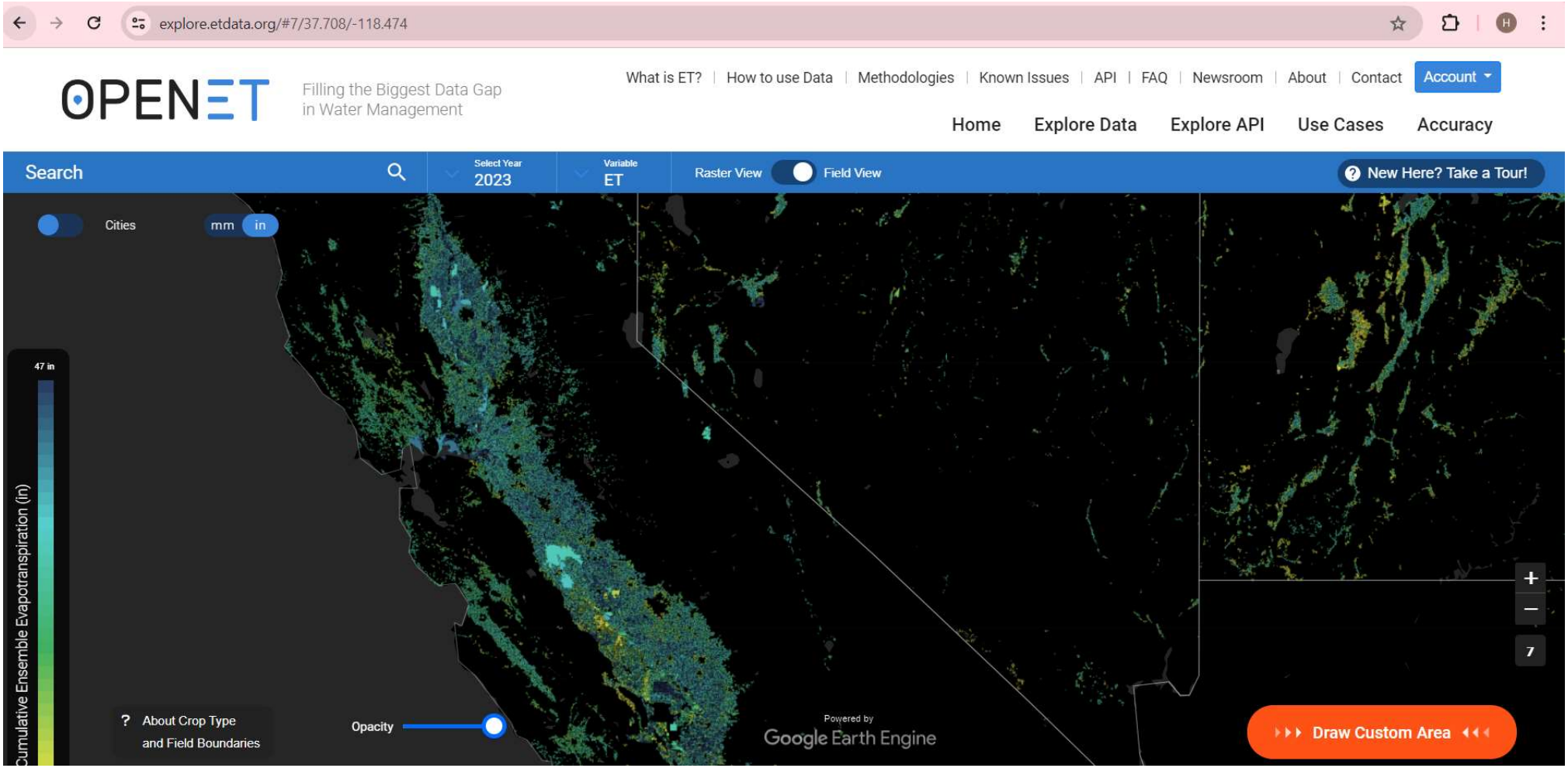
(1984-2021)



Importance of Satellite data



Given assumptions on scaling pathways and drought's impact on values of water, the average *annual* water savings are estimated to be 241,000 acre-feet, and value to farmers is estimated to be $45.5 M, while economic benefits reach $127.6 M over the period 2028–2033.


explore.etdata.org/#7/37.708/-118.474
OPENET
Filling the Biggest Data Gap in Water Management
What is ET? | How to use Data | Methodologies | Known Issues | API | FAQ | Newsroom | About | Contact
Account
Home
Explore Data
Explore API
Use Cases
Accuracy
Search
Select Year
2023
Variable
ET
Raster View
Field View
New Here? Take a Tour!
Cities
mm
in
47 in
Cumulative Ensemble Evapotranspiration (in)
About Crop Type and Field Boundaries
Opacity
Powered by
Google Earth Engine
Draw Custom Area
7

Training Objectives

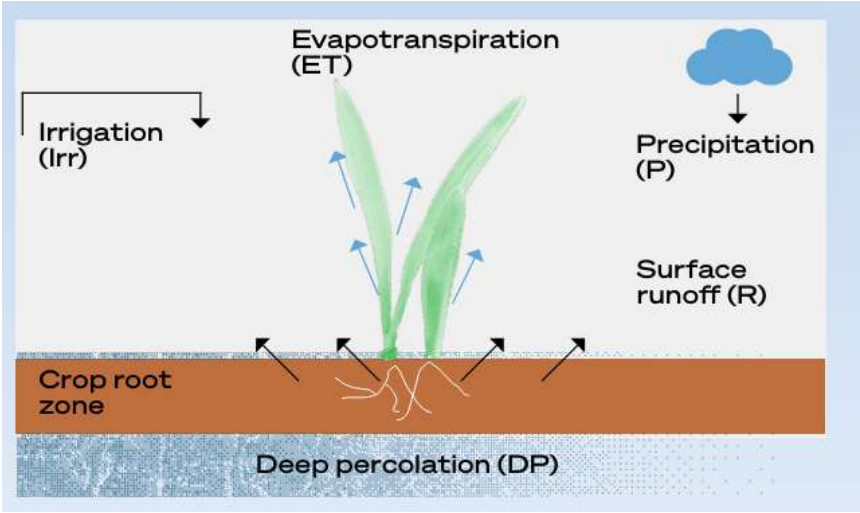
- Understand the importance of remote sensing in estimating groundwater use from irrigation.
- Learn the methodology for estimating groundwater use from irrigation using remote sensing data, particularly focusing on evapotranspiration (ET) and precipitation.
- Gain practical skills in using online platforms and tools to access and analyze satellite data.

Methodology Overview

- Locate the area of interest.
- Identify agricultural lands within the area.
- Differentiate between irrigated and non-irrigated lands.
- Determine the source of irrigation water (surface or groundwater).
- If possible, map surface water diversions from streams.
- Estimate evapotranspiration (ET) of irrigated agricultural lands using remote sensing data (Landsat, Sentinel-2, VIIRS).
- Estimate precipitation using remotely sensed products (CHIRPS).
- Calculate groundwater use using mass balance
- Validate the results using field measurements (when available).

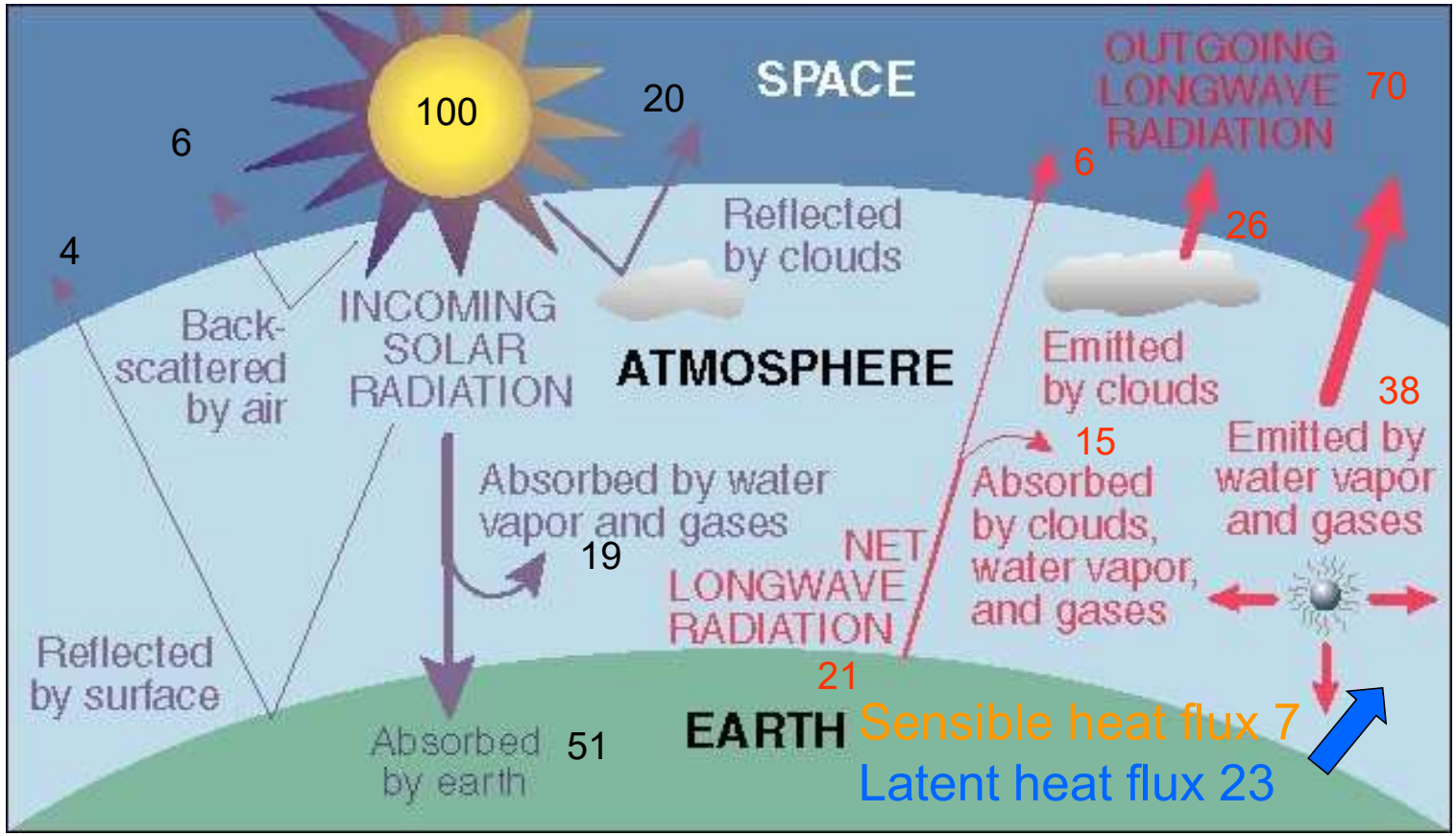
Importance of Evapotranspiration (ET)

- Evapotranspiration (ET) is the combined process of evaporation (from soil) and transpiration (from plants).
- It represents the largest consumer of freshwater globally.
- In arid regions, most ET from agricultural fields originates from irrigation.
- By estimating ET, we can indirectly assess groundwater use for irrigation.



https://www.fao.org/support-to-investment/news/detail/en/c/1634668/

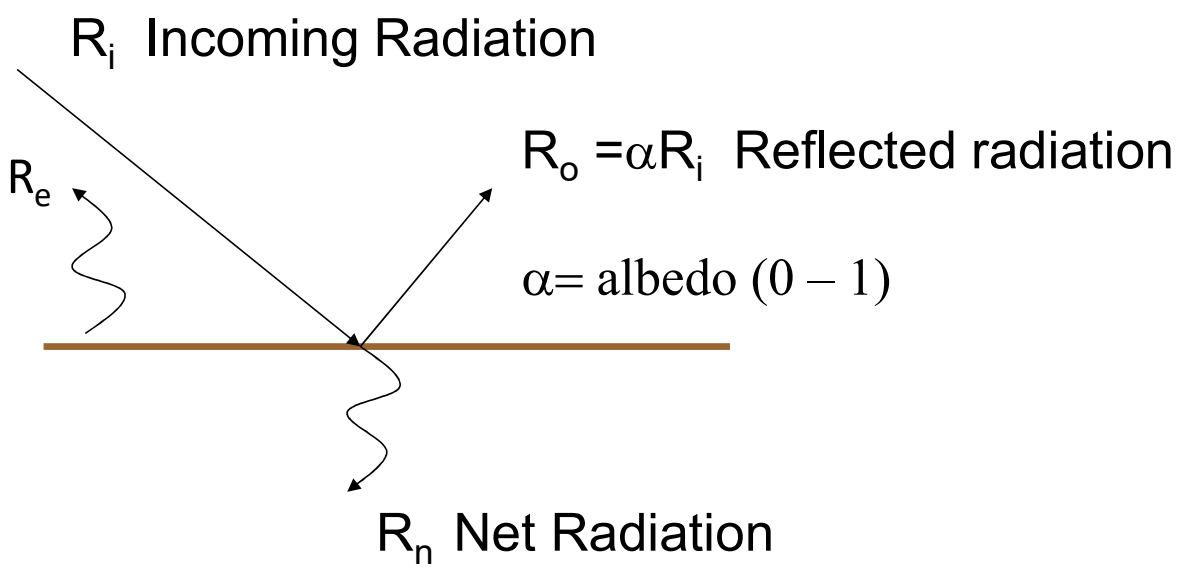
How can we estimate ET from space?



http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/energy/radiation_balance.html

Net Radiation, R_n

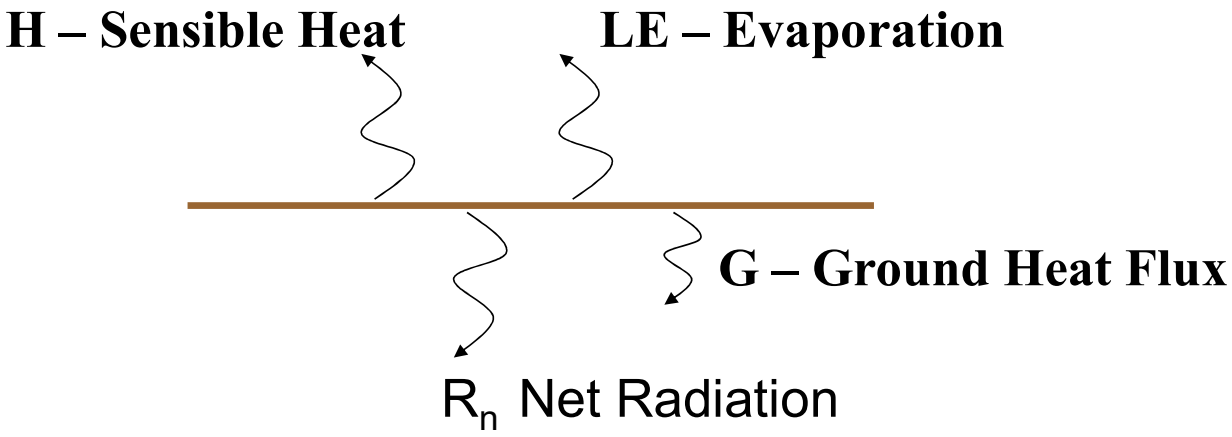
$$R_n = R_i(1-\alpha) - R_e$$



Average value of R_n over the earth and over the year is 105 W/m^2

Net Radiation, R_n

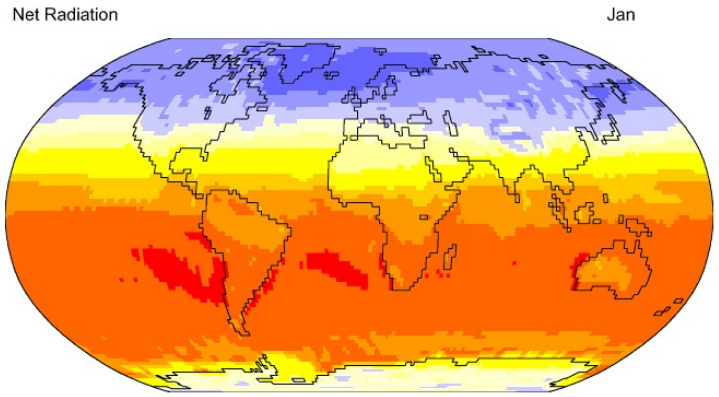
$$R_n = H + LE + G$$



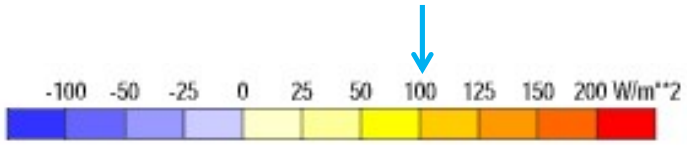
Average value of R_n over the earth and over the year is 105 W/m^2

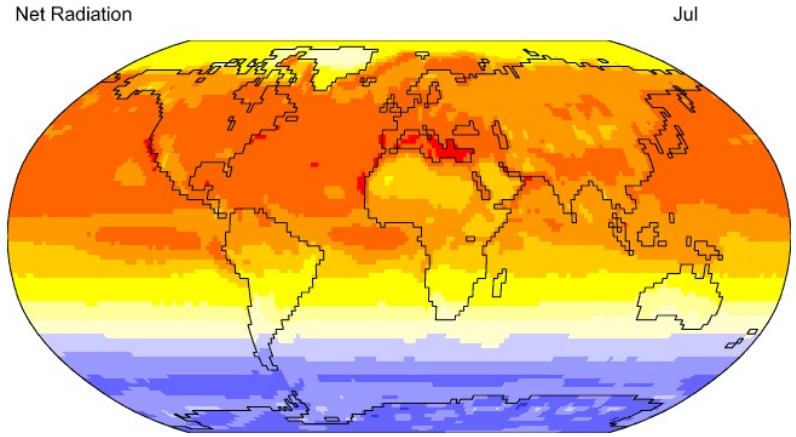
Net Radiation

http://geography.uoregon.edu/envchange/clim_animations/flash/netrad.html



Mean annual net radiation over the earth and over the year is 105 W/m^2





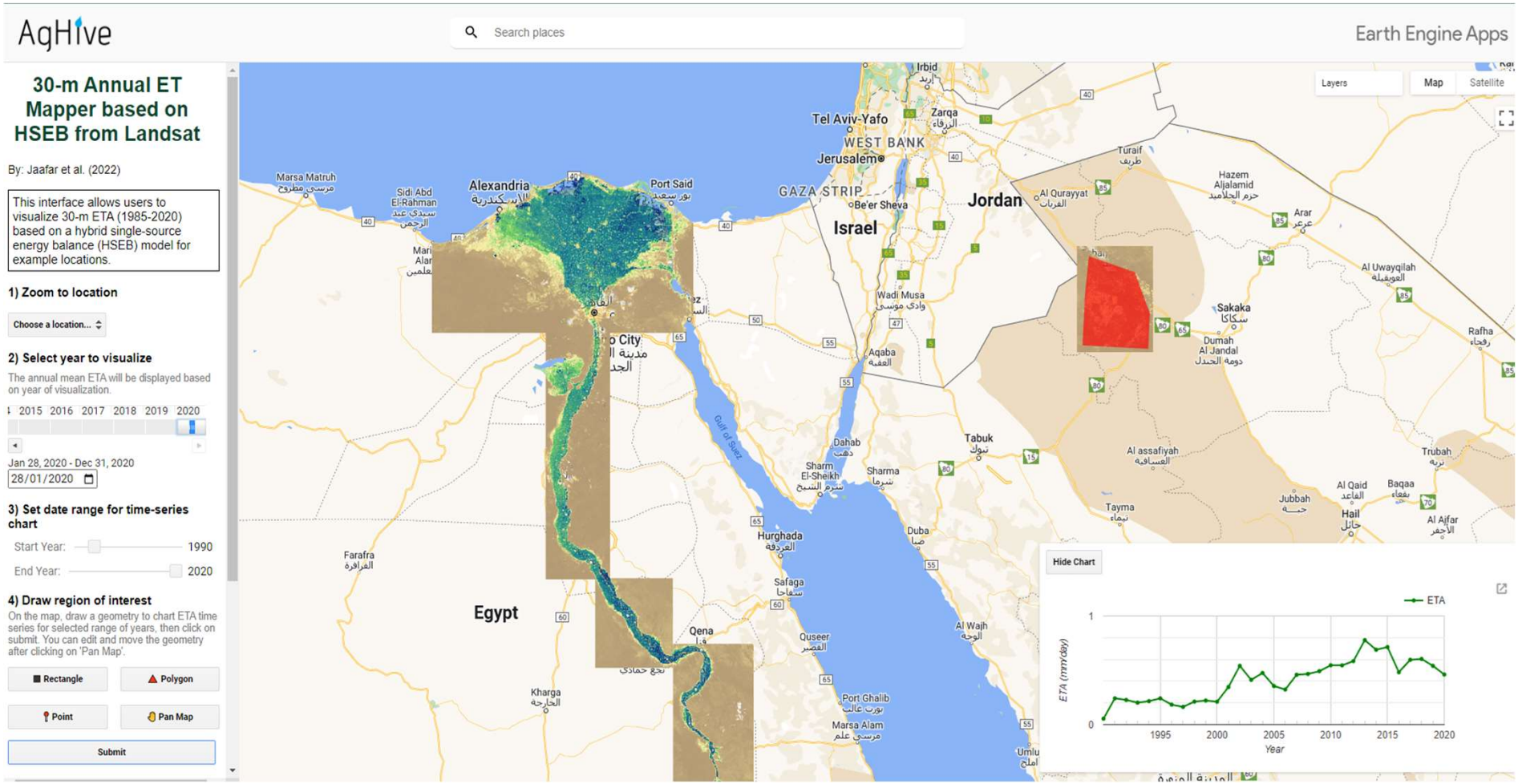
Energy Balance Method

$$\frac{28.4\ \mathrm{W}}{m^2} \times \frac{J/s}{W} \times \frac{1\ g}{2450\ J} \times \frac{3600\ s}{1\ hr} \times \frac{24\ hr}{1\ day} \times \frac{m^3}{1000\ kg} \times \frac{1\ kg}{1000\ g} \times \frac{1000\ mm}{1\ m} = 1\ \frac{mm}{day}$$

(λ → $\frac{1\ g}{2450\ J}$; ρ_w → $\frac{1\ kg}{1000\ g}$)

$$ET = \frac{\lambda E}{28.4} = \frac{1}{28.4}(R_n - G - H - W)$$

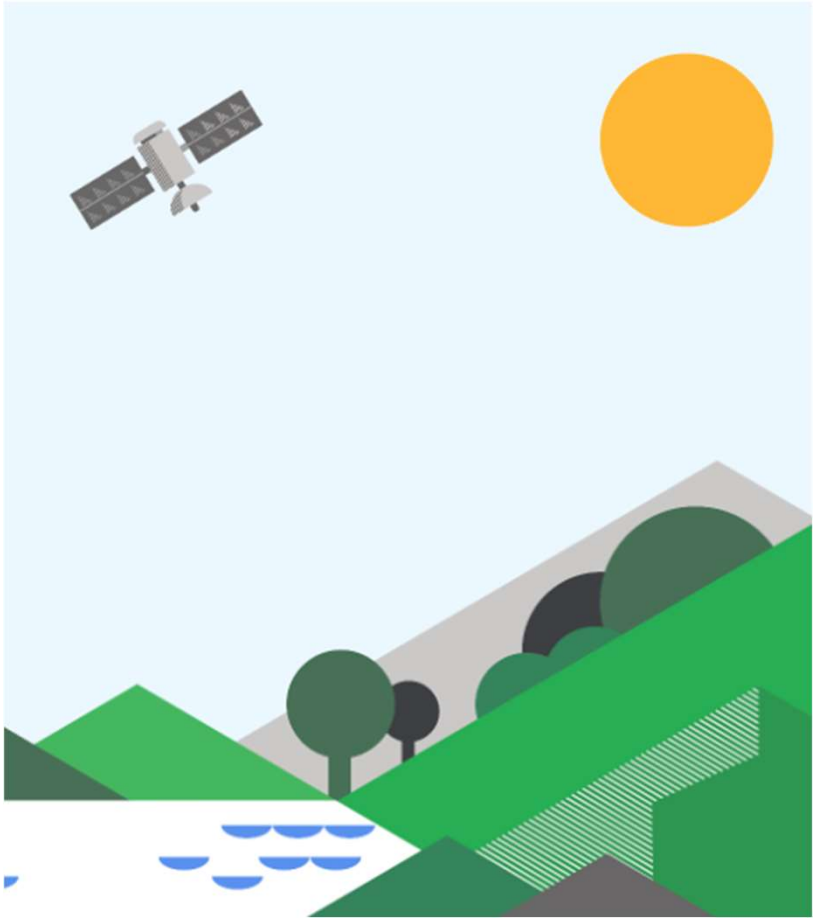
The maximum radiative evaporation rate $E_r = \frac{R_n}{28.4}$


AgHive
Search places
Earth Engine Apps
30-m Annual ET Mapper based on HSEB from Landsat
By: Jaafar et al. (2022)
This interface allows users to visualize 30-m ETA (1985-2020) based on a hybrid single-source energy balance (HSEB) model for example locations.
1) Zoom to location
Choose a location...
2) Select year to visualize
The annual mean ETA will be displayed based on year of visualization.
2015 2016 2017 2018 2019 2020
Jan 28, 2020 - Dec 31, 2020
28/01/2020
3) Set date range for time-series chart
Start Year: 1990
End Year: 2020
4) Draw region of interest
On the map, draw a geometry to chart ETA time series for selected range of years, then click on submit. You can edit and move the geometry after clicking on 'Pan Map'.
Rectangle
Polygon
Point
Pan Map
Submit
Layers
Map
Satellite
Egypt
Israel
Jordan
WEST BANK
GAZA STRIP
Jerusalem
Tel Aviv-Yafo
Alexandria
Port Said
Be'er Sheva
Aqaba
Sharm El-Sheikh
Hurghada
Qena
Kharga
Farafra
Tabuk
Sakaka
Gulf of Suez
Hide Chart
ETA
ETA (mm/day)
Year
1995
2000
2005
2010
2015
2020

How can we estimate ET in the field

Remote Sensing Data for ET Estimation

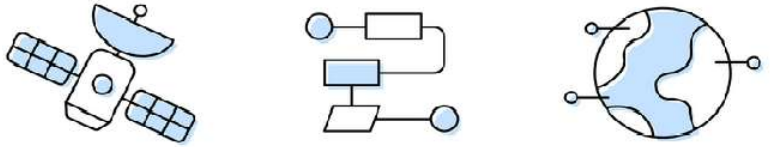
- Several remote sensing data sources can be used to estimate ET:
- Visible Infrared Imaging Radiometer Suite (VIIRS) - daily data, 1 km resolution
- MODIS
- ECOSTRESS
- Landsat 8 & 9 - 8-day coverage, 30 m resolution
- Sentinel-2 - 5-day coverage, 10 m resolution (often fused with Sentinel-3 for higher temporal resolution)
- UAV data
- Others



Accessing Remote Sensing Data

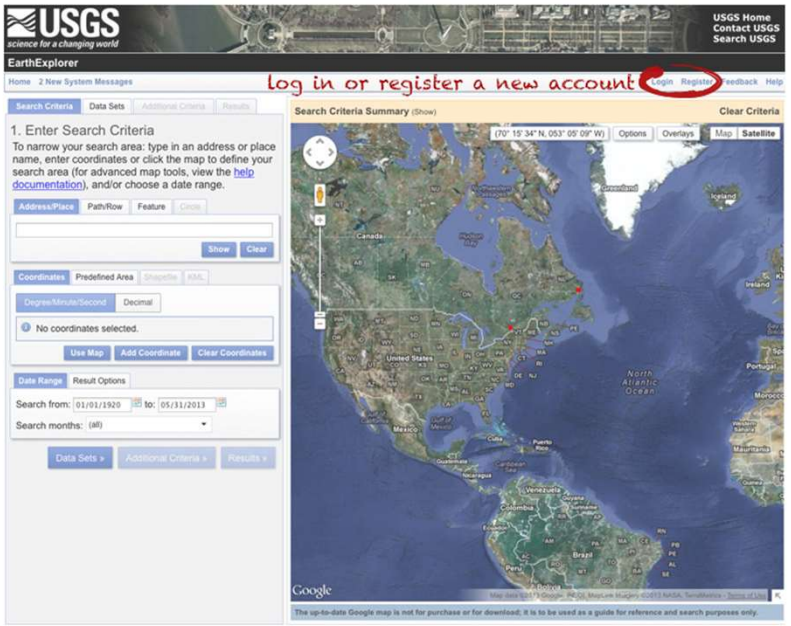
- Platforms like Google Earth Engine (GEE) and Earth Explorer offer free access to various satellite data archives.
- Signing up for accounts on these platforms is a prerequisite for data access.
- This training will guide you through the account creation process on both platforms.

Google Earth Engine



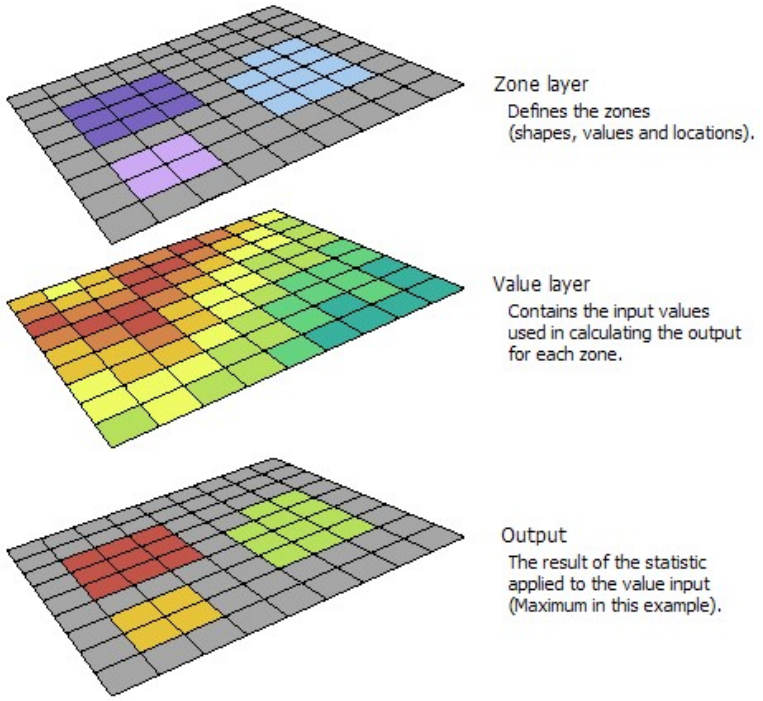
Downloading Landsat ET Maps from EarthExplorer

- EarthExplorer allows users to search for and download specific Landsat data products.
- We will focus on acquiring Landsat Evapotranspiration (ET) maps for this training.
- The training will provide step-by-step instructions on searching, filtering, and downloading the desired data.



Estimating Evapotranspiration with ArcGIS

- ArcGIS software provides tools for calculating averages of ET from downloaded Landsat data over specific areas.
- This training will demonstrate how to utilize ArcGIS functionalities for ET estimation.



Rainfall Estimation using Earth Engine

- Google Earth Engine (GEE) offers functionalities for analyzing and processing satellite data.
- This training will introduce how to use GEE code for rainfall analysis.

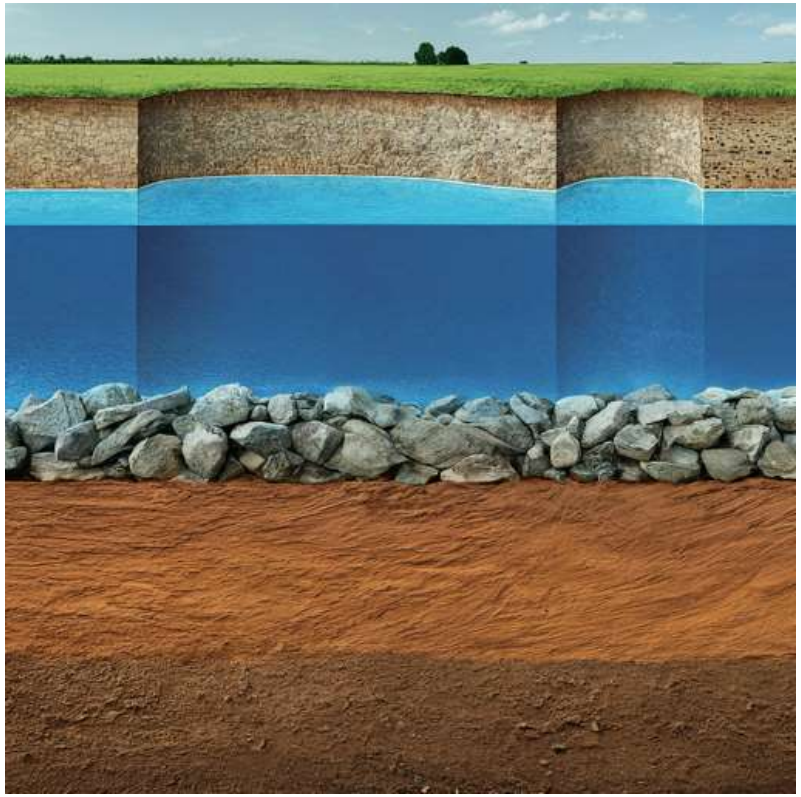
Determining Effective Rainfall

- Not all precipitation contributes to groundwater recharge.
- Part of the rainfall gets stored in the root zone of plants and evaporates later.
- Effective rainfall represents the portion that infiltrates the soil and contributes to groundwater.
- We will calculate effective rainfall by integrating ET and precipitation data.

Calculating Groundwater Use

- We can estimate groundwater use using the following formula:
- In areas with negligible surface flow and for extended periods, the last two terms can be assumed negligible.

Net rainfall = Precipitation (P) - Evapotranspiration (ET) - Surface Flow (SF) - Change in Soil Water Storage (ΔS)/Time (Δt)



Data Validation

- Validation is crucial to ensure the accuracy and reliability of our groundwater use estimates.
- Ideally, we compare our results with field measurements of groundwater levels or pumping rates.
- If field data is unavailable, comparisons with other established methods or regional models can be used for validation.

Conclusion

- By applying this methodology, water managers can:
  - Improve irrigation water use efficiency
  - Develop informed water allocation strategies
  - Promote sustainable water management practices

Q&A

- We welcome your questions!